

## SEMICONDUCTOR LIGHT-EMITTING ELEMENT

### Background of the invention

#### Field of the invention

**[0001]** This invention relates to a semiconductor light-emitting element, particularly a multilayered light-emitting element to generate and emit a white color light which is composed of plural epitaxial layers grown on a substrate.

#### Related Art Statement

**[0002]** Recently, an attention is paid to a blue color light-emitting element made of III-V semiconductor compounds or II-VI semiconductor compounds, and in reality, a GaN-based semiconductor light-emitting element and a ZnSe-based semiconductor light-emitting element are developed as such a blue color light-emitting element. In addition, a white color light-emitting element is also proposed by taking advantage of the blue color light-emitting element.

**[0003]** For example, in "Optic Functional Material's Manual", p457, June, 1997, published by Optronics Ltd., such a white color light-emitting element as composed of a GaInN-based LED including a sapphire single crystal and an active layer made of GaInN and a YAG fluorescent substance is disclosed.

**[0004]** Moreover, in Japanese Laid-open Patent Publication Kokai Hei 2000-49374 (JP A 2000-49374), such a white color light-emitting element as to generate and emit a white color light by superimposing a blue color light or a blue-green color light emitted from a GaInN-based active layer and a yellow color light from the fluorescent color center of a GaN substrate which is excited by the blue color light or the blue-green color light, is disclosed.

**[0005]** In this manner, various white color light-emitting elements using GaN-based blue color light-emitting elements are proposed, but white color light-emitting elements using ZnSe-based blue color light-emitting elements are not almost proposed, and thus, strongly desired.

### Summary of the Invention

**[0006]** It is an object of the present invention to provide a new white color light-emitting element made of II-VI semiconductor compounds such as ZnSe-based semiconductor compounds.

**[0007]** For achieving the above object, this invention relates to a semiconductor

light-emitting element comprising:

a substrate,

a first epitaxial layer group to emit a yellow color light which is provided on the substrate and made of II-VI semiconductor compounds, and

a second epitaxial layer group to emit a blue color light which is provided on the substrate and made of II-VI semiconductor compounds.

[0008] As mentioned above, in the present invention, on a substrate are provided and stacked a first epitaxial layer group and a second epitaxial layer group which are made of II-VI semiconductor compounds. Then, a yellow color light is generated and emitted from the first epitaxial layer group and a blue color light is generated and emitted from the second epitaxial layer group. Therefore, by superimposing the yellow color light and the blue color light, a given white color light can be obtained from the semiconductor light-emitting element entirely.

[0009] In this case, by controlling the chromaticities and the intensities of the yellow color light and the blue color light independently, various white color lights such as a warm white color light or a cold white color light can be obtained. Moreover, the brightness of the thus obtained white color light is not reduced by the combination of the yellow color light and the blue color light. As a result, a much brighter white color light can be obtained in the semiconductor light-emitting element than in a conventional one.

#### Brief Description of the Drawings

For better understanding of the present invention, reference is made to the attached drawings, wherein

Fig. 1 is a structural view showing a semiconductor light-emitting element according to the present invention,

Fig. 2 is a structural view showing another semiconductor light-emitting element according to the present invention,

Fig. 3 is a graph showing the relation between the chromaticity and the bandgap in a II-VI semiconductor compound,

Fig. 4 is a graph showing the relation between the lattice constant and the bandgap in a II-VI semiconductor compound,

Fig. 5 is another graph showing the relation between the lattice constant and the bandgap in a II-VI semiconductor compound,

Fig. 6 is a structural view showing a first epitaxial layer group, and Fig. 7 is a structural view showing a second epitaxial layer group.

Description of the Preferred Embodiments

**[0010]** This invention will be described in detail with reference to the accompanying drawings.

**[0011]** Fig. 1 is a structural view showing a semiconductor light-emitting element according to the present invention, and Fig. 2 is a structural view showing another semiconductor light-emitting element according to the present invention.

**[0012]** Semiconductor light-emitting elements 10 and 20 include substrates 1, first epitaxial layer groups 3 as a yellow color light-emitting elements via first buffer layers 2, second epitaxial layer groups 5 as blue color light-emitting elements via second buffer layers 4, respectively.

**[0013]** On the second epitaxial layer group 5 are provided p-type contact electrode device 6, respectively, and on the exposed surfaces of the second buffer layers 4 are provided p-type electrodes 7, respectively. In addition, in the semiconductor light-emitting element 10, on the exposed surface of the first buffer layer 2 is provided an n-type electrode 8, and in the semiconductor light-emitting element 20, on the backside surface of the substrate 1 is provided another n-type electrode 8.

**[0014]** In either case, by applying a given voltage between the p-type contact electrode device 6; the p-type electrode 7 and the n-type electrode 8, to flow an electric current through the first epitaxial layer group 3 and the second epitaxial layer group 5, the first epitaxial layer group 3 and the second epitaxial layer group 5 are excited, to generate and emit a yellow color light and a blue color light, respectively. In the semiconductor light-emitting element 10 or 20, the yellow color light and the blue color light are superimposed and thus, a given white color light is generated and emitted.

**[0015]** The yellow color light and the blue color light are generated and emitted from the first epitaxial layer group 3 and the second epitaxial layer group 5, independently. Therefore, by controlling the chromaticities and the intensities of the yellow color light and the blue color light independently, various white color lights such as a warm white color light or a cold white color light can be obtained. Moreover, the brightness of the thus obtained white color light is not reduced by the

combination of the yellow color light and the blue color light. As a result, a much brighter white color light can be obtained in the semiconductor light-emitting element than in a conventional one.

**[0016]** Fig. 3 is a graph showing the relation between the chromaticity and the bandgap in a II-VI semiconductor compound, and Figs. 4 and 5 are graphs showing the relation between the lattice constant and the bandgap in a II-VI semiconductor compound, respectively.

**[0017]** In order to obtain a white color light from the combination of the yellow color light and the blue color light, the inventors investigated the constructions of the first epitaxial layer group 3 and the second epitaxial layer group 5 on the basis of the graphs shown in Figs. 3-5.

**[0018]** Fig. 6 is a structural view showing a first epitaxial layer group. In Fig. 6, the first epitaxial layer group 3 includes an n-type cladding layer 3-1, an n-type optical waveguide layer 3-2 provided on the n-type cladding layer 3-1, and a light-emitting active layer 3-3 provided on the n-type optical waveguide layer 3-2. Moreover, the first epitaxial layer group 3 includes a p-type optical waveguide layer 3-4 provided on the light-emitting active layer 3-3 and a p-type cladding layer 3-5 provided on the p-type optical waveguide layer 3-4.

**[0019]** Electrons and positive holes are injected into the light-emitting active layer 3-3 from the n-type optical waveguide layer 3-2 and the p-type optical waveguide layer 3-4, respectively, and are combined, to emit a given color light.

**[0020]** The n-type cladding layer 3-1 and the p-type cladding layer 3-5 function as barrier layers for the light-emitting active layer 3-3.

**[0021]** In view of Figs. 3-5, it is desired that the light-emitting active layer 3-3 is made of a II-VI semiconductor compound including Zn, Se, Te and Cd, particularly having a composition of  $\text{Zn}_{1-X}\text{Cd}_X\text{Se}_{1-Y}\text{Te}_Y$  ( $0 < X < 0.4$ ,  $0 < Y < 0.4$ ). In this case, since the  $\text{Zn}_{1-X}\text{Cd}_X\text{Se}_{1-Y}\text{Te}_Y$  semiconductor material has a bandgap energy within 2.132-2.172eV, it can generate and emit a yellow to yellow green color light stably if it is excited.

**[0022]** The n-type cladding layer 3-1, the p-type cladding layer 3-5, the n-type optical waveguide layer 3-2 and the p-type optical waveguide layer 3-4 are made of normal II-VI semiconductor compounds, respectively. In the case of the light-emitting active layer 3-3 being made of the above-mentioned semiconductor

material, it is desired that the n-type cladding layer 3-1 through the p-type optical waveguide layer 3-4 are made of II-VI semiconductor compounds including Be and Mg, particularly having a composition of (BeMgZn)Se.

**[0023]** Fig. 7 is a structural view showing a second epitaxial layer group.

In Fig. 7, a second epitaxial layer group 5 includes an n-type cladding layer 5-1, an n-type optical waveguide layer 5-2 provided on the n-type cladding layer 5-1 and a light-emitting active layer 5-3 provided on the n-type optical waveguide layer 5-2. Moreover, the second epitaxial layer group 5 includes a p-type optical waveguide layer 5-4 provided on the light-emitting active layer 5-3 and a p-type cladding layer 5-5 provided on the p-type optical waveguide layer 5-4.

**[0024]** Electrons and positive holes are injected into the light-emitting active layer 5-3 from the n-type optical waveguide layer 5-2 and the p-type optical waveguide layer 5-4, respectively, and are combined, to emit a given color light from the light-emitting active layer 5-3.

**[0025]** The n-type cladding layer 5-1 and the p-type cladding layer 5-5 function as barrier layers for the light-emitting active layer 5-3.

**[0026]** In view of Figs. 3 and 5, the light-emitting active layer 5-3 is made of a II-VI semiconductor compound including Zn, Cd, Se and Be. Moreover, in view of Figs. 3 and 4, the light-emitting active layer 5-3 may be made of a II-VI semiconductor compound including Zn, Se, Te and Cd, particularly having a composition of  $\text{Zn}_{1-Z}\text{Cd}_Z\text{Se}_{1-V}\text{Te}_V$  ( $0 < Z < 0.1$ ,  $0 < V < 0.1$ ). In this case, since the  $\text{Zn}_{1-Z}\text{Cd}_Z\text{Se}_{1-V}\text{Te}_V$  semiconductor material has a bandgap energy within 2.528-2.675eV, it can generate and emit a blue green to blue color light stably if it is excited.

**[0027]** The n-type cladding layer 5-1, the p-type cladding layer 5-5, the n-type optical waveguide layer 5-2 and the p-type optical waveguide layer 5-4 are made of normal II-VI semiconductor compounds, respectively. In the case of the light-emitting active layer 5-3 being made of the above-mentioned semiconductor material, it is desired that the n-type cladding layer 5-1 through the p-type optical waveguide layer 5-4 are made of II-VI semiconductor compounds including Be and Mg, particularly having a composition of (BeMgZn)Se.

**[0028]** In the first and the second epitaxial layer groups 3 and 5, the light-emitting active layers 3-3 and 5-3 may be made of single layers or quantum dots, respectively. If the light-emitting active layers 3-3 and 5-3 are made such quantum

dots, the mismatches in lattice constant of the layers 3-3 and 5-3 can be mitigated.

**[0029]** If the first buffer layer 2 and the second buffer layer 4 are made of ZnSe semiconductors, the mismatches in lattice constant between the semiconductor layers constituting the semiconductor light-emitting elements 10 and 20 as shown in Figs. 1 and 2 can be mitigated.

**[0030]** In the semiconductor light-emitting elements 10 and 20, the p-type contact electrode device 6 may be made of a p-type BeTe contact layer/p-type ZnSe cap layer/p-type layer electrode.

**[0031]** The p-type electrodes 7 and the n-type electrodes 8 may be made of normal electrode materials, respectively.

**[0032]** The substrates 1 may be made of normal substrate materials available by persons skilled in the art, particularly made of a GaAs substrate or a InP substrate.

**[0033]** Although the present invention was described in detail with reference to the above examples, this invention is not limited to the above disclosure and every kind of variation and modification may be made without departing from the scope of the present invention.

**[0034]** For example, in the semiconductor light-emitting elements 10 and 20 as shown in Figs. 1 and 2, the first epitaxial layer group 3 as a yellow light-emitting element is provided on the downside, and the second epitaxial layer group 5 as a blue light-emitting element is provided on the upside. However, the other way round will do.

**[0035]** In the first epitaxial layer group 3 and the second epitaxial layer group 5 as shown in Figs. 5 and 6, the lower semiconductor layers from the light-emitting active layers 3-3 and 5-3 are made of n-type semiconductor compounds, and the upper semiconductor layers from the light-emitting active layers 3-3 and 5-3 are made of p-type semiconductor compounds. However, the other way round will do.

**[0036]** As mentioned above, the semiconductor light-emitting element of the present invention has, on a given substrate, the first epitaxial layer group to emit a yellow color light and the second epitaxial layer group to emit a blue color light which are made of II-VI semiconductor compounds. Therefore, the semiconductor light-emitting element can generate and emit various white color lights such as a warm white color light or a cold white color light can be obtained. Moreover, the brightness of the thus obtained white color light is not reduced by the combination

